The Implications of Frequently Encountered Grading Factors on the Processing Quality of Durum Wheat

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ABSTRACT

Grading factors associated with adverse growing conditions affect the processing value of durum wheat. Mycotoxins associated with fungal infections like Fusarium head blight and ergot partition themselves among milling products, and are relatively stable throughout pasta processing. Fusarium head blight also has adverse effects on semolina milling, gluten strength and pasta color. Durum wheat frequently is segregated according to protein content in recognition of the primary importance of protein content in determining cooked pasta texture. Hard vitreous kernels are a widely used durum wheat grade specification because nonvitreous kernels are lower in protein content and softer than vitreous kernels. The softness of nonvitreous kernels results in a lower yield of coarse semolina, an important factor to many durum wheat millers. Damage due to orange wheat blossom midge is tolerated in low amounts in top durum wheat milling grades because of increased specks in semolina. Other factors that cause surface discoloration such as smudge, black-point and mildew are also tolerated in low amounts to avoid specks in semolina. Severe frost damage is a serious grading factor, resulting in lower semolina yield, poor semolina refinement (high ash, dull color, specks) and poor spaghetti color. Severe frost damage also reduces gluten quality. Moderate pre-harvest sprouting has little impact on durum wheat quality providing that mildew damage is not present. Even when sprout damage is severe there is little effect on pasta cooking quality, aside from an increase in solids lost to cooking water. The starch degrading enzyme α-amylase associated with pre-harvest sprouting has little opportunity to react during pasta processing because of the relatively low moisture content of pasta dough and rapid loss of moisture during early stages of pasta drying, and is quickly denatured during cooking. Heat damage due to improper use of hot air dryers harms gluten functionality and if severe can reduce pasta cooking quality. Recent advances in durum wheat milling and pasta processing such as debranning, a trend to finer semolina granulation for high capacity pasta presses, and the general acceptance of high temperature pasta dryers are significantly impacting on the relative importance of grading factors on durum wheat processing quality.

INTRODUCTION

Wheat physical condition is influenced by environmental conditions during growth and harvest. Some of the commonly encountered forms of environmental damage can have serious implications on wheat processing quality (Dexter and Tipples 1987, Dexter 1993). Therefore, most wheat producing countries market wheat on the basis of physical attributes, as determined by grading and classification systems. An ideal system strikes a balance between the interests of wheat processors and producers. Wheat grade standards should be set to ensure segregation according to processing potential, while allowing the maximum possible proportion of wheat in the top grades to maximize return.

In Canada the Canadian Grain Commission (CGC) is responsible for setting grade standards for all grains and oilseeds. CGC wheat grade standards are set on a scientific basis so that physical damage permitted accurately reflects processing implications. An ongoing collaborative research effort by the Grain Research Laboratory (GRL) and Industry Services divisions of the CGC ensures that grade standards are fair and effective.

Recently we reviewed the effects of commonly encountered grading factors on common wheat end-use quality (Dexter and Edwards 1998). The implications of grading factors on the processing potential on durum wheat merit separate discussion, because quality implications are different than common wheat (Feillet and Dexter 1996). Grading factors associated with surface discoloration of kernels are more important for durum wheat because bright speck-free semolina is

essential to give the aesthetic appearance required for successful marketing of premium pasta products. This article summarizes the results of recent research on frequently encountered grading factors that affect the safety and processing value of durum wheat, and assesses the significance of each grading factor on semolina milling and pasta quality.

FACTORS AFFECTING EDIBILITY

Ergot

Ergot is a fungal parasite (*Claviceps purpurea*) that infects cereals and grasses at the flowering stage, ergot bodies growing in place of kernels. Ergot contains alkaloids, which are toxic to animals, poultry and humans (Lorenz 1979).

Strict tolerances for ergot are universally required when marketing durum wheat because of toxicity of associated ergot alkaloids. Published studies on retention of ergot alkaloids in wheat milling fractions and end-products have focused primarily on common wheat (Dexter and Edwards 1998 and references therein), but similar considerations apply to durum wheat. The concentration of ergot alkaloids will depend on extraction rate, milling technique (grinding conditions and mill flow) and the component streams of a given milled product. Using common wheat flour, Fajardo et al. (1995) showed that retention of ergot alkaloids is not influenced by pasta drying temperature, and that 40 to 60% of ergot alkaloids are lost during cooking due to the combined effects of thermal denaturation and leaching into cooking water (Table 1).

Ergot in durum wheat has no detectable effect on semolina extraction rate, physical dough properties or pasta cooking quality (Dexter and Matsuo 1982). However, at levels as low as about 12 kernel size pieces of ergot per 500 g, the upper limit allowed in No 3 Canada Western Amber Durum (CWAD), semolina was significantly speckier, although pasta brightness and hue were not affected.

Specks in semolina attributable to ergot are a serious aesthetic defect because they are dark and highly visible in pasta. Ergot bodies are difficult to remove on the basis of size because they assume the kernel dimensions of infected wheat as they develop in spikelets. Ergot bodies are low in specific weight, and can be removed effectively by gravity tables (Dexter et al. 1991).

Fusarium Head Blight

Fusarium head blight (or scab) has captured attention recently because of outbreaks in Canada and the United States in recent years. Fusarium head blight outbreaks are a safety concern because of mycotoxins in *Fusarium*-infected grain.

Numerous studies have concluded that the most prevalent mycotoxin, deoxynivalenol (vomitoxin, DON) is stable during milling and secondary processing, although it becomes partitioned in varying concentrations among screenings and mill products (Dexter and Edwards 1998; Pomeranz 1990). Nowicki et al. (1988) determined the DON levels in mill fractions and pasta from severely infected durum wheat. They found that DON concentration in semolina was about 80% of that of cleaned wheat, and that concentration was reduced further by 50% following cooking. Dexter et al. (1997) reported DON

concentrations in semolina declined an average of 50% for ten less severely infected durum wheat cultivars harvested in Manitoba in 1995.

Safety remains the primary concern with Fusarium head blight outbreaks, but there can be serious effects on wheat milling and processing (Dexter et al. 1996, 1997). Moore (1994) reported that Fusarium damage in durum wheat imparts poor pasta color. Dexter et al. (1997) found that levels of infection around 2%, the maximum tolerated in lower milling grades of CWAD, adversely affected semolina yield and refinement (color and speck count) (Table 2). That caused a trend, readily discernible by eye, towards redder (higher a*) and duller (lower L*) pasta. Fusarium damage caused slightly weaker gluten, but pasta cooking quality was not affected. They concluded that the strict Fusarium damage tolerances for No 1 CWAD (0.25%) and No 2 CWAD (0.5%) were warranted on the basis of processing potential.

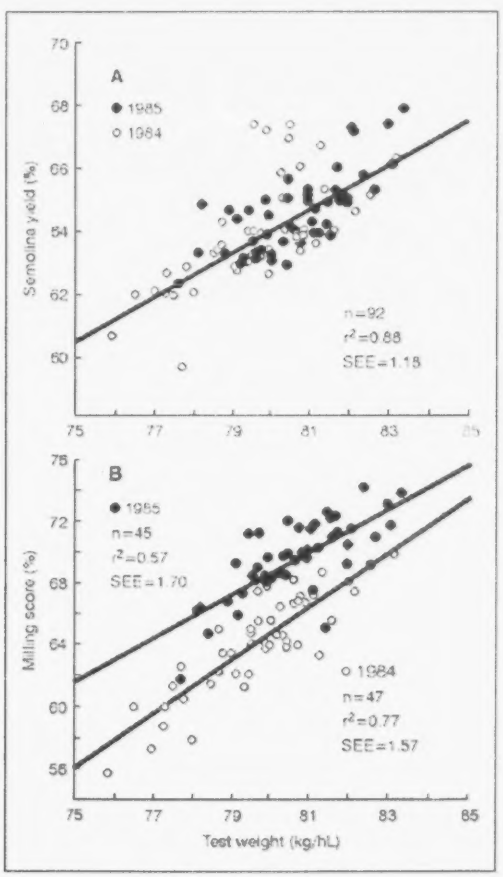
FACTORS AFFECTING PROCESSING

Test Weight

Test weight is a widely recognized primary specification in wheat grading because it is related to the degree of soundness of wheat. Test weight is often used as an index of milling potential, but there is no consensus on its true value as a milling yield predictor (Hook et al. 1984). Different wheat classes and different varieties within a wheat class exhibit different relationships between test weight and milling yield. Test weight is affected by moisture content, weathering, kernel

size and density, and packing factors which have little direct relationship to milling potential.

Test weight is a useful index for durum wheat milling potential. Dexter et al. (1987) found a strong relationship between CWAD semolina yield and test weight for durum wheat for two consecutive crop years (Figure 1A). Increasing semolina ash content with decreasing test weight caused a dramatic drop in semolina milling score (semolina yield at constant ash content) as test weight declined (Figure 1B). Watson et al. (1977) also concluded that test weight was an effective indicator of milling potential for American durum wheat.



Protein content

Protein content is the most important quality characteristic influencing pasta cooking quality (Matsuo et al. 1982a; Autran et al. 1986; D'Egidio et al. 1990). The relationship is complex and is influenced by other factors, notably protein content and processing conditions, but generally, as protein content increases, pasta becomes firmer and less sticky. Pasta made from high protein semolina is physically strong and elastic. High protein cooked pasta is firm, non-sticky and resilient, and retains its texture if overcooked. Pasta produced from low protein semolina is deficient in some or all of these characteristics.

The relationship of protein content to pasta cooking quality is evident from CGC CWAD harvest survey data over the past 10 years (Table 3). High rainfall in western Canada over the past five years has low protein content, due to high wheat yields. The previous five years were drier, and protein content was higher. Pasta cooking scores were clearly superior during the higher protein period.

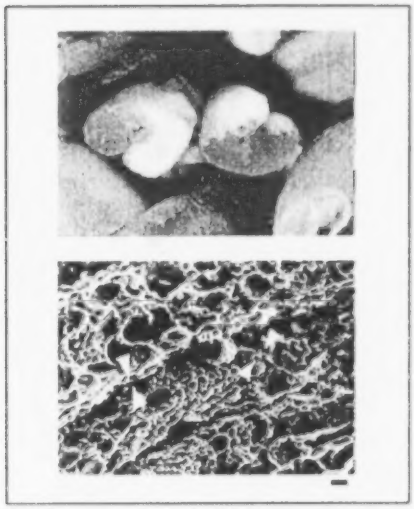
Durum wheat is often traded at guaranteed minimum protein content levels. Countries such as Japan, the United States and Spain have legislation and/or labeling laws that stipulate minimum protein content levels in the finished product. In Canada low protein content in recent harvests has necessitated segregating the top three grades of CWAD by protein content to meet minimum specifications of discriminating customers. However, unlike protein segregation of wheat classes such as hard red spring wheat, protein segregation of durum

wheat is not the complete solution to demands from the marketplace. Medium to low protein hard red spring wheat can be used for high quality products (hearth bread, Asian noodles etc.). In contrast, low protein durum wheat remaining after segregation of high protein material has low market acceptance and lower value because it has limited application outside the pasta industry.

Yellow Berry (nonvitreous, starchy or mealy kernels)

Yellow berry (mealy kernels, starchy kernels) is a physical property of wheat that is a primary durum wheat marketing factor. Starchy kernels occur when insufficient nitrates are available during grain development. Starchy kernels are important because they are lower in protein content and softer that vitreous kernels (Dexter and Matsuo 1981; Dexter et al. 1988; Dexter et al. 1989a).

Starchy zones in wheat kernels are opaque and appear chalky when cut (Figure 2). This is due to air pockets in starchy zones. Vitreous zones have a compacted continuous structure, with starch granules tightly bound within a protein matrix. Starchy zones are less compacted, implying less protein than in vitreous zones. However, protein content and protein composition of vitreous and starchy zones in piebald kernels are similar (Dexter et al. 1989a). Starchy zones may occur in piebald kernels because there is insufficient protein to create a sufficiently strong matrix to fully contract all regions during final stages of maturity as kernels desiccate.



As discussed earlier, durum wheat often is marketed with a minimum protein content guarantee. When protein content is specified hard vitreous kernel content is less important, but the softer texture of starchy kernels is still a milling factor. The relationship between starchy kernels and durum wheat milling performance is complex, but generally starchy kernels yield less coarse semolina and more flour, reducing durum wheat milling potential in markets where coarse semolina is preferred.

Bolling and Zwingelberg (1972) found that durum wheat semolina yield was more related to wheat origin than to wheat vitreousness. Internationally recognized procedures (ISO and ICC) define fully vitreous kernels as "those that do not disclose the least trace of farinacious endosperms", a definition adopted by the CGC. Matveef (1963) proposed that fully starchy kernels should be given

more emphasis that piebald kernels when estimating durum wheat vitreousness. Piebald kernels are lower in protein content that vitreous kernels, but they are almost as hard as vitreous kernels (Table 4). Fully starchy kernels are significantly softer, and cause lower yield of coarse semolina.

The impact of starchy kernels on semolina yield varies from miller to miller, depending on semolina granulation targets. Over 25 years ago Menger (1971) questioned the importance of starchiness on durum wheat milling, given a tend to finer semolina granulation. Since then the trend to finer granulation has become more apparent, as major pasta equipment manufacturers recommend finer granulation for modern high capacity presses.

Orange wheat blossom midge

In our previous article (Dexter and Edwards 1998) we summarized the very serious quality problems that occur when the orange wheat blossom midge (*Sitodiplosis mosellana* Géhin) attacks common wheat. Orange wheat blossom midge eggs are deposited on florets during heading and flowering, and larvae feed on developing grain. Severe midge infestation has devastating effects on crop yield unless insecticide treatments are applied soon after infestation is apparent. Grain from midge-damaged common wheat exhibits high protein content, poor milling quality and weak gluten.

In 1995 and 1996 midge damage was a major grading factor for CWAD and American durum wheat. Gluten quality is an important secondary quality factor for pasta cooking quality (Feillet and Dexter 1996). However, the high protein

content associated with midge damage could offset the adverse effect of midge damage on gluten strength.

The CGC conducted an extensive survey following the 1995 harvest to evaluate the importance of midge-damage on CWAD processing performance (Dexter and Marchlyo unpublished data). Results confirmed that the protein content of midge-damaged durum wheat tended to be high. There was little evidence that gluten quality, measured by the SDS-sedimentation test and wet gluten yield, was damaged (Table 5). As a result pasta texture was not affected.

Midge damage had a serious effect on durum wheat semolina milling performance (Table 5). As midge damage increased, semolina refinement (ash content, color and speck count) declined and pasta became less bright and undesirably brown (long dominant wavelength). Yellow pigment in semolina and yellowness of pasta (purity) were not affected. Severely midge damaged kernels, which were rotted and blackened, presumably from attack by fungi, were particularly detrimental to semolina refinement and spaghetti color.

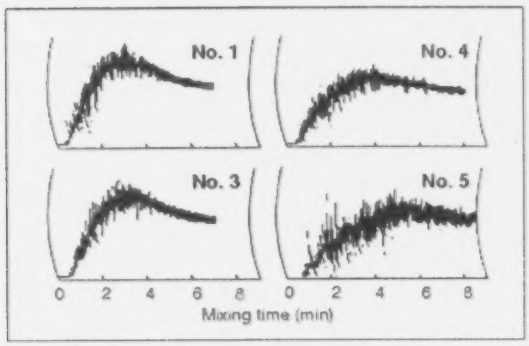
Frost damage and immaturity

The short growing season in western Canada and the northern United States makes wheat vulnerable to frost damage and immaturity. Effects of frost damage on common wheat has received considerable attention (Dexter and Edwards 1998 and references therein). Severe frost damage is one of the most serious quality defects associated with common wheat because of adverse effects on wheat milling performance and baking quality.

Dexter and Matsuo (1981) examined the effects of immaturity and moderate frost damage on the milling and pasta-making quality of CWAD wheat using hand-picked samples from the 1979 harvest (Table 6). They found that the main effects were loss of semolina refinement (high ash content and more specks) and duller and browner spaghetti (longer dominant wavelength).

In 1992 frost damage and immaturity were the predominant grading factors associated with the Canadian durum wheat crop. That permitted Dexter et al. (1994) to prepare a series of samples grading from No 1 CWAD to feed quality (No 5 CWAD) solely due to frost damage and immaturity. They verified that increasing immaturity and moderate frost damage caused a gradual decline in semolina refinement and a concomitant deterioration in spaghetti color.

Gluten properties were affected by severe frost damage. CWAD downgraded to No 3 on account of frost damage exhibited a Mixograph curve comparable to No 1 CWAD because severe frost damage is not allowed in No 3 CWAD (Figure 3). CWAD downgraded to No 4 CWAD, which contains some severe frost damage, gave a significantly weaker curve, and No 5 CWAD gave an abnormal curve. Due to the inclusion of some severe frost damage in No 4 CWAD there was a pronounced deterioration in semolina milling yield, semolina refinement and pasta color, but cooking quality was not greatly affected (results not shown).



Sprout damage, weathering and mildew

Pre-harvest sprouting due to damp harvest conditions has serious adverse effects on bread quality (Dexter and Edwards 1998 and references therein) The starch degrading enzyme α-amylase is present in very high levels in sprouted wheat. Alpha-amylase degrades starch during mixing and fermentation reducing the water holding capacity of starch which causes lower baking absorption and dough that is sticky and hard to handle.

The effect of sprout damage on durum wheat processing quality is less obvious. There is general agreement that sprout damage alone has little if any effect on semolina milling performance (Donnelly 1980; Matsuo et al. 1982b; Dexter et al. 1990). Debbouz et al. (1995) found that minor bleaching (weathering) caused by rain at harvest, involving only discoloration of the seed coat, did not affect semolina properties or pasta color.

Sprout damage is often associated with mildew damage, caused by a fungus (*Cladosporium*) which poses no toxicological threat, but can cause semolina milling problems. Light mildew damage is characterized by grey tufts of spores at

distal ends of damaged kernels. Severely mildewed kernels become blackened and rotten. Unless they are removed during cleaning moderately to severely mildew damaged kernels in durum wheat cause dark specks in semolina (Dexter and Matsuo 1982).

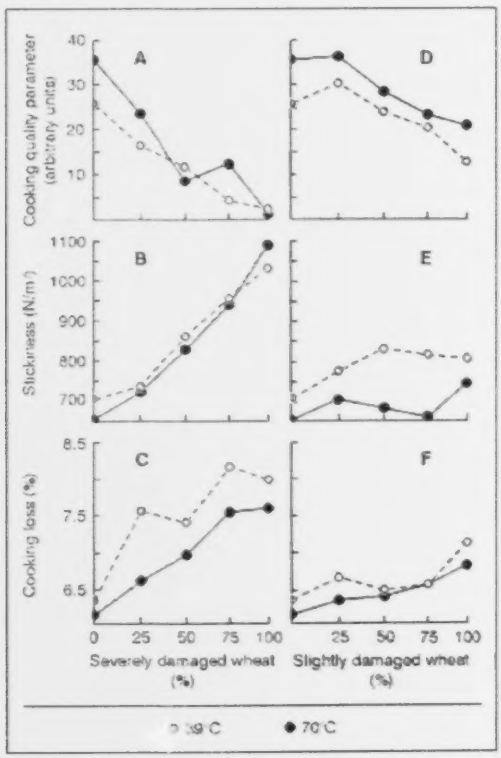
Deleterious effects of sprout damage on bread making quality are exacerbated by degradation of starch by α-amylase during fermentation. The lower water content of pasta dough and rapid loss of moisture during drying provides α-amylase with little opportunity to degrade starch during processing (Dexter et al. 1990). During cooking, α-amylase is heat denatured rapidly by penetration of cooking water (Kruger and Matsuo 1982).

Canadian (Matsuo et al. 1982), French (Combe et al. 1988) and American (Dick et al. 1974) studies have concluded that sprout damage has little effect on pasta texture. As durum wheat Falling Number (FN) declines to about 150 seconds, there is no effect on pasta cooking quality (Table 7). At lower FN, which corresponds to sprout damage far in excess of levels encountered in durum wheat marketed for high quality pasta, there are slight influences on pasta cooking quality and amount of solids lost to cooking water. Production problems such as uneven extrusion, strand stretching and irregularities in drying ('checking' or cracking of strands during storage) have been attributed to sprout damage, but only when damage is very severe (Donnelly 1980; Combe et al. 1988).

Heat damage

Wheat growing areas of North America usually are favorable for drying grain naturally in the field. However, occasionally wet harvests can result in damp grain. Improper storage of damp grain, or artificial drying at too high a temperature can cause heat damage. In extreme cases kernels turn black and emit a charred odor (binburnt kernels). Binburnt kernels are a serious quality defect in durum wheat even at low levels because of highly visible dark specks in semolina.

Binburnt kernels are readily detectable visually. However, damage to gluten functionality by artificial drying may occur without visual evidence. Heat damage has little effect on semolina refinement or pasta appearance (Dexter et al. (1989b). However, heat damage to gluten proteins influences physical dough properties, and when severe, can result in unsatisfactory pasta cooking quality (Figure 4).



Durum wheat heat damage can be detected from mixing curves. Moderately heat damaged durum wheat exhibits pronounced delay in reaching peak dough consistency, and peak consistency is reduced. A rapid micro-milling and mixing procedure adapted from the method of Preston et al. (1989) is effective in detecting heat damage in durum wheat (Dexter et al. 1989b).

Preston and Symons (1993) developed a rapid simple heat damage test that estimates the extent of protein fibril formation when a ground sample is wetted. When viewed by bright field microscopy the extent of fibril formation clearly relates to degree of heat damage, from moderate to serious. The method was developed for bread wheat, but is equally applicable to durum wheat.

Smudge and black-point

Surface discoloration due to fungi such as *Alternaria alternata* and *Dreschlera tritici-repentis* pose no toxicological danger, but are serious quality defects in durum wheat. The main concern is dark specks in semolina that cause aesthetic defects in pasta (Dexter and Matsuo 19882; Dexter 1993).

In western Canada *Alternaria alternata* is a very common cause of "black-point", darkening confined to the germ end, and "smudge", a more progressed form of the infection which has spread along the crease and sides of kernels. Smudge and black-point have little effect on semolina milling yield, semolina ash, spaghetti color (except a slight trend to less brightness) or spaghetti cooking quality (Table 8). However, an increase in specks is readily apparent.

In some years red smudge, a pinkish discoloration caused by *Dreschlera tritici-repentis*, is the predominant CWAD grading factor (Dexter 1993). Unless the infection is well progressed and induces surface darkening similar to that of black-point and smudge, quality effects are not serious, and are confined to a slight increase in semolina speckiness.

CONCLUDING REMARKS

Common grading factors in durum wheat have different degrees of importance than for common wheat. The necessity for bright speck-free semolina that produces pasta with excellent aesthetic appearance makes grading factors that cause surface discoloration of far more importance for durum wheat. As a result the top Canadian and American durum wheat grades tolerate very low levels of grading factors such as smudge, black-point, severe midge, etc. Protein content is more important than gluten strength in determining pasta cooking quality, so factors detrimental to durum wheat gluten strength have less impact on end-product texture than for bread wheats.

Grade standards are strictly maintained to ensure durum wheat millers of quality required to give desired semolina milling performance. However, ongoing evolution of durum wheat processing requires continual review of tolerances for individual grading factors. A trend to finer semolina granulation may reduce the importance of HVK on durum wheat marketability. Increasing popularity of debranning of durum wheat before milling could reduce the importance of surface discoloration (Dexter and Wood 1996).

High temperature (HT) and ultra-high temperature drying have become universally accepted in pasta processing. HT yields firmer, less sticky pasta than traditional low temperature (LT) drying cycles (Dexter et al 1981). As a result raw material quality, particularly protein content, can be compromized when using HT technology without sacrificing pasta textural properties

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FIGURE CAPTIONS

Figure 1. Relationship of test weight of CWAD to semolina yield (A) and to semolina yield at constant ash content (milling score, B). Source: Dexter et al. (1987).

Figure 2. The structure of piebald (partially starchy) durum wheat kernels. Top, external view showing chalky appearance of starchy zone. Bottom, scanning electron micrograph showing starchy-vitreous interface. Source: Dexter et al. (1989a).

Figure 3. Semolina mixograph mixing curves for No 1 CWAD and samples downgraded to No 3, No 4 and No 5 CWAD solely on the basis of frost damage and immaturity. Source Dexter et al. (1994).

Figure 4. Effect of severe heat damage (A,B,C) and moderate heat damage (D,E,F) on durum wheat spaghetti cooking properties. Source: Dexter et al. (1989b).

Table 1.

Concentration of ergot alkaloids (ppb) in pasta dried by low temperature (LT) and high temperature (HT), and in cooked pasta and cooking water.

Product	LT spaghetti	HT spaghetti
Spaghetti:		
Dried	280	260
Cooked	180	120
Cooking water	30	26

Source: Farjardo et al. (1995). Alkaloid contents expressed on 14% moisture basis.

Table 2.

Effect of Fusarium damage on some quality properties of Kyle and Hercules amber durum wheat.

Property	Kyle		Hercules	
	CL	AS	CL	AS
Wheat:				
Fusarium damage, %	0.04	2.4	0.2	3.8
DON, µg/g	0.7	2.1	1.2	3.9
Test weight, kg/hL	79.3	78.8	78.9	78.4
Protein, %	15.2	14.8	15.2	15.2
Semolina yield, %	69.8	68.2	71.3	71.1
Semolina:				
Ash, %	0.73	0.75	0.76	0.76
AGTRON color, %	44	43	53	48
Specks per 50 cm^2	93	121	66	69
Mixograph:				
Mixing time, min	3.50	3.42	3.50	3.25
Peak height	67	64	70	65
Spaghetti:				
Color:				
L*	69.4	68.7	72.1	70.4
a*	6.0	6.7	5.1	7.5
b*	55.7	55.7	56.5	55.1
Firmness, kg/10 strands	1.22	1.23	1.12	1.12

Source: Dexter et al. (1997). Analytical data expressed on 14% moisture basis.

Abbreviations: CL = cleaned by hand removal of obviously damaged kernels; AS = as harvested; DON = deoxynivalenol (vomitoxin).

Table 3.

No 1 CWAD wheat protein content and pasta cooking score (cooking quality parameter, CQP).

Harvest Year	Protein %	CQP units	Harvest Year	Protein %	CQP units
1997	12.7	33	1992	13.0	37
1996	12.4	33	1991	12.6	46
1995	12.1	38	1990	14.1	56
1994	12.5	36	1989	15.0	57
1993	11.9	28	1988	15.5	54
5 year mean	12.3	34	5 year mean	14.0	50

Source: Canadian Grain Commission Harvest Survey Data.

Abbreviations: CQP = cooking quality parameter, a score combining cooked pasta firmness and resilience.

Table 4.

Protein content and hardness (particle size index) of vitreous, piebald and starchy kernels from three durum wheat cultivars.

Sample	Protein	PSI
	%	%
Coulter:		
Vitreous	11.8	28.6
Piebald	10.0	33.7
Fully starchy	9.7	46.2
Wascana		
Vitreous	10.7	36.6
Piebald	8.8	37.8
Fully starchy	7.9	48.5
Wakooma		
Vitreous	11.8	28.6
Piebald	10.0	33.7
Fully starchy	9.7	46.2

Source: Coulter: Dexter et al. (1988); Wascana and Wakooma: Dexter et al. (1989b).

Table 5.

Effect of midge damage and severe midge damage on the milling and pasta-making quality of CWAD wheat from the 1995 harvest.

Property	Sample 1	Sample 2	Sample 3
Wheat			
Midge damage, %	3.7	6.9	6.7
Severe midge damage, %	0.4	1.8	8.6
Test weight, kg/hL	81.5	80.7	80.5
Protein content, %	14.2	14.3	14.5
SDS-sedimentation, mL	32	34	31
Semolina yield, %	66.1	66.5	67.3
Semolina			
Protein content, %	12.9	13.3	13.2
Wet gluten, %	32.2	32.6	33.1
Ash content, %	0.65	0.69	0.71
AGTRON color, %	68	62	58
Yellow pigment, ppm	7.5	7.5	7.6
Specks per 50 cm^2	58	70	126
Spaghetti			
Color			
Brightness, %	47.6	45.5	43.9
Purity, %	52.4	51.5	51.3
Dominant wavelength, nm	577.2	577.7	578.2
Cooking score, units	70	69	71

Source: Dexter and Marchylo, internal Canadian Grain Commission report. Analytical values on 14% mb.

Table 6.

Effect of moderate frost damage on milling and spaghetti properties of CWAD wheat.

Property	No 1 CWAD	No 3 CWAD
Wheat:		
Light frost, %	0	10
Test weight, kg/hL	84.1	81.3
Protein content, %	14.7	15.0
Semolina yield, %	68.6	66.7
Semolina:		
Protein content, %	13.8	14.0
Ash content, %	0.68	0.73
Specks per 50 cm^2	13	20
Spaghetti:		
Color:		
Brightness, %	45.2	43.4
Purity, %	59.4	58.2
Dominant wavelength, nm	577.9	578.1
Cooking score, units	14	17

Source: Dexter and Matsuo (1981). A sample of 1979 crop CWAD wheat was hand-picked to give a frost-free sample (No 1 CWAD) and a sample enriched in frost damaged kernels (No 3 CWAD).

Table 7.

Effect of sprout damage on durum wheat Falling Number, semolina α-amylase activity and pasta cooking quality.

CWAD grade	Sprout damage, %	Wheat Falling Number, seconds	Semolina α-amylase activity, units	Spaghetti cooking loss, %	Spaghetti firmness, nm/sec
1	0	360	34	6.2	37
2	1.3	250	144	5.9	34
2	2.2	216	193	5.6	36
3	3.5	196	350	6.5	38
3	7.0	179	402	6.3	38
4	10.4	101	876	6.9	46
4	12.5	80	1363	8.0	50

Source: Matsuo et al. (1982). Firmness measured as rate of shear, lower values indicating greater firmness.

Table 8.

Effect of smudge and black-point on CWAD processing quality.

Property	Sample A Control	Sample A Smudged	Sample B Control	Sample B Smudged
Wheat:				
Grade	1 CWAD	3 CWAD	2 CWAD	4 CWAD
Smudge, %	0	3	0	3
Black-point, %	0	8	3	7
Test weight, kg/hL	83.5	83.2	83.9	83.0
Protein, %	13.3	13.5	13.3	13.5
Semolina yield, %	69.5	68.3	68.7	69.1
Semolina:				
Ash, %	0.71	0.71	0.68	0.70
Specks per 50 cm^2	48	79	55	124
Spaghetti:				
Color:				
Brightness, %	45.4	45.1	47.1	44.3
Purity, %	57.9	57.0	57.7	56.4
Dominant wavelength, nm	578.0	578.0	577.6	577.7
Cooking score, units	12	9	12	12

Source: Dexter and Matsuo (1982). Samples of 1979 (A) and 1980 (B) crop CWAD wheat were hand-picked to give samples free of smudge and black-point (control) and enriched in smudge and black-point (smudged). Analytical data expressed on 14% moisture basis.